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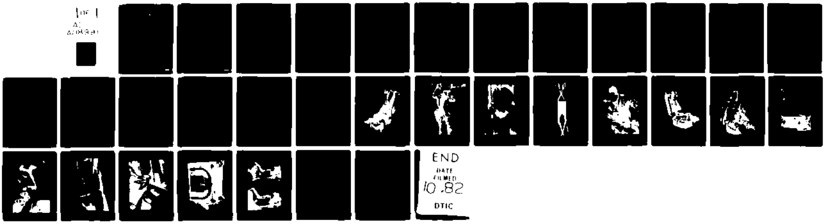

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PRELIMINARY DEVELOPMENT OF THE XV ("EX-VEE") AIRCREWMAN RESTRAINT

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Aircraft and Crew Systems Technology Directorate
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Warminster, Pennsylvania 18974

11 MAY 1982

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High-performance aircraft undergoing air combat manuvers often subject aircrewmen to acceleration loads which displace them so far out of position that they can no longer control their aircraft. The XV restraint harness is being designed to reduce vertical (Z) displacement of aircrewmen in ejection seat equipped aircraft; it is also a parachute harness.

Initial testing indicates that the XV restraint harness provides improvement over the MA-2 torso harness for inflight acceleration loads. In addition, it is adjustable for all size crewmen, is seat mounted, and provides either manual or automatic release of the parachute, survival kit, and harness upon water immersion.

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SUMMARY

Preliminary tests of the XV ("Ex-Vee") restraint harness at $-G_z$ acceleration indicates that it offers about a 3-centimeter (2 in.) reduction in z displacement compared to the existing MA-2 harness.

Perhaps the most important feature of the strap routing is that the crewman is provided with both upper and lower torso $-G_Z$ restraint. If the crewman doesn't adequately tighten his lower restraint before experiencing $-G_Z$, then the upper restraint will take up most of the load.

Several other important features are available with this design:

1. It is seat mounted and adjustable for all size crewmen;
2. It provides excellent upper torso restraint, yet permits the aircrewman to turn around to look aft;
3. It is easy and fast to adjust, doff, and don;
4. A manual single point release is available for emergency ground and water egress;
5. It functions as a parachute harness;
6. It provides automatic release of the parachute, survival kit, and restraint straps upon water immersion. This feature should considerably reduce the large number of drownings attributed to parachute entanglement;
7. The system is retrofittable on U.S. Navy ejection seats; the main modifications required are to the survival kit lid;
8. Because the harness is open on the sides, it reduces the heat stress on the aircrewman. This is especially important when the aircrewman wears an antiexposure garment;
9. Since the restraint straps, survival kit, and parachute are all automatically released upon water immersion, the life preserver need not provide so much buoyancy. It could be made smaller to improve aircrewman comfort and to reduce the chance of parachute entanglement.

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INTRODUCTION

During the past 25 years the MA-2 harness has proven to be an adequate aircrewman restraint for normally encountered flight loads. However, with the advent of more maneuverable aircraft, the probability of departures from controlled + G flight has increased. Several years ago it was a rare pilot indeed that could claim more than two minutes of his total flight time at $-G_z$. Today, pilots are flying more time under higher "G" loads in all directions and the MA-2 harness does not appear adequate to the task.

The problems associated with the MA-2 harness as an inflight restraint were thoroughly tested and documented by Bason and Etheredge, (reference 1). As a direct result of their excellent work further investigation has been directed by the NAVAIRSYSCOM to determine if either a simple modification of the MA-2 harness or another operational system might provide improved inflight restraint, (reference 2).

Before the Naval Air Development Center (NAVAIRDEVCEN) began this test program it seemed worthwhile to determine which features would be desirable in the ideal fighter aircraft restraint system.

1. SPECIFICATIONS FOR AN IDEAL FIGHTER AIRCREWMAN RESTRAINT SYSTEM

   A. It must provide solid inflight retention of the aircrewman without interfering with his control of the aircraft. Expected operational accelerations; $\pm 6G_x$, $\pm 3G_y$, $+8G_z$, $-2G_z$.

   B. It must allow the crewman to have upper body mobility (180° rotation) so he can observe the trail of incoming missiles in order to perform evasive maneuvers.

   C. It must provide lower torso restraint at all times but upper torso restraint only when needed (i.e., high-turbulence, spins, departures, and ejection).

   D. It should provide $-30G_x$ crash protection.

   E. It should permit prepositioning of the aircrewman for ejection loads.

   F. It must prevent limb flailing injuries from high-"Q" forces encountered during ejection.

   G. It must safely distribute parachute opening loads.

   H. It should enable the crewman to make a safe parachute landing on the ground or in the water.

   I. It must provide for quick disconnect from the parachute and survival kit, including an automatic release feature upon water immersion.

   J. The restraint should be adjustable for all size aircrewmen.

K. It must be easy and fast to adjust, don, and doff.

L. The restraint should not allow a great deal of heat buildup on the aircrewman.

M. The system should require very little maintenance, and have high reliability.

N. The restraint should be retrofittable to existing aircraft.

O. The system should be cost effective.

As the various operational harnesses and the modifications to the MA-2 harness were examined at the NAVAIRDEVCEN, it became apparent that they would not provide all the features which were desirable. The provision of a special feature such as a single-point release very often precluded another feature such as good $-G_z$ restraint. If good $-G_z$ restraint was provided this often precluded upper torso rotation. Obviously, some design compromises had to be made on the ideal specifications. But just how many features could be effectively incorporated into one restraint system? The XV ("Ex-Vee") restraint was the direct outcome of seeking to answer this question.

Three XV prototype harnesses were fabricated at the NAVAIRDEVCEN to determine the potential effectiveness of this approach. Although only limited testing has been done at the NAVAIRDEVCEN and at the Naval Air Test Center (NAVAIRTESTCEN), the results were encouraging enough to report that this concept could be developed into an operational system and that it offers many desirable features.

DISCUSSION

1. PRIORITY OF DESIGN CONSTRAINTS.

The large amount of interfacing required to make aircrew member life support, safety, and survival equipment compatible makes it absolutely necessary to orchestrate all systems when any new piece of equipment is introduced. Compromises must be made according to a proper set of priorities. The first consideration must be the ability of the crewman to accomplish the mission assigned with a maximum chance of success. Secondly, a life support system needs to provide adequate survivability of the aircrewman in case of an emergency.

A major constraint in designing an improved restraint system is that it should be retrofittable with only minor modifications to either the ejection seat or the aircraft. This restricts the design to the use of a three point attachment with possibly a fourth point forward on the survival kit or seat (negative "G" or fifth strap).

2. STRAP ROUTING

Because of the flexibility of the human torso, the inflight restraint problem is best considered in two parts: lower torso, and upper torso, as indicated in reference 1. One way to route straps for lower torso restraint is over the thighs and directly down into the survival kit or seat pan (figure 1a). The upper torso restraint needs to support $-G_X$, $\pm G_Y$, and $-G_Z$. Since the inertia reel, a part of the upper restraint, supports the torso for $-G_X$ accelerations, additional straps must take care of the other acceleration loads. Two cross chest straps will handle $\pm G_Y$ and $-G_Z$ but they would not properly take the parachute opening loads because there would be a tendency for these straps to pull in towards the crewman's head (figure 1b). Therefore, a vertical strap must be added at each shoulder to take out these parachute loads (figure 1c). Since upper torso and lower torso straps all should begin and end at the two back survival kit fittings, these were selected as the logical points to release the XV restraint.

The XV MOD 0 restraint (figures 2, 3, 4, and 5) was designed to improve restraint support in all directions with all of these ideas in mind. It initially tested out to be a very "solid" inflight restraint for $-G_Z$. Its main fault was that it restrained the upper torso too well for air combat maneuvers; the crewman was not able to turn around without loosening the shoulder straps.

The XV MOD 1 system was designed to correct this fault. A roller fitting was placed at the crewman's shoulder point (figure 6); this combined the vertical strap and the cross chest strap together into a strap that comes up the crewman's side, through the roller, and down across the chest to the opposite side of the survival kit.

The main features of this restraint were:

a. Improved $-G_Z$ inflight restraint over the MA-2 integrated torso garment;

b. The crewman had upper torso mobility;

c. Single point release system;

d. Seat mounted harness; one size fits all;

e. Easy and fast to doff and don;

f. Low-heat stress;

g. Automatic release of chute, survival kit, and restraint upon water entry and;

h. The system was retrofittable; the only modification required was to the survival kit lid.

It met many of the requirements of an ideal system, however, a major shortcoming of both the MOD 0 and MOD 1 harnesses was that the parachute suspension proved uncomfortable because the RSSK-8 survival kit formed the bottom half of the parachute suspension sling. The kit forced the crewman's back to bow forward. Also, the crewman's thighs were wedged tight enough to reduce blood circulation (figures 3 and 4).

A third version, the XV MOD 2 system, was designed to correct this fault by providing a release feature on the forward negative "G" strap (figures 7 and 8). Upon seat-man separation after an ejection, the survival kit tips forward and the phenolic roller which anchors the negative "G" straps behind the kit is free to slide under the kit and permits the aircrewman to be comfortably suspended in the lower restraint sling.

Some additional changes must yet be made to the lower restraint straps so they can retain a snug fit when the crewman becomes suspended under his parachute.

In the final anlysis, strap routing is a tradeoff between what is best for restraint and what is most comfortable. If the lower straps are routed over the iliac crest (and assuming they don't slip off) the pelvic displacement could be minimized by painfully tightening the straps. If the lower straps are routed over the thighs, this permits a bit more z displacement due to muscle compression but it also permits better upper torso rotation for the crewman.

Upper torso restraint is desirable only if it permits torso rotation. But, if rotation is permitted, then the restraint is ineffective for side loads. The only way to meet all restraint features is to provide an automatic system of strap tighteners or air bladders. At this time, these options were not being considered.

3. DESIGN OF THE MANUAL/AUTOMATIC HARNESS RELEASE SYSTEM

All of the single point release harnesses examined by the author required some compromises in the routing of straps in order to permit all straps to terminate at the release fitting (figure 9). This release fitting was usually located at the crewman's waist—a very mobile point on which to anchor. The XV restraint design eliminates this problem by providing two release fittings which are solidly fixed to the survival kit lid. By originating and terminating all straps at these fittings it is possible to obtain a simple and firm strap routing.

The first prototype release fittings (MOD 0 and MOD 1) utilized a pivoting bolt with its front end locked into a cone shaped slot with a cone shaped washer (figure 10). The washer was retained on the bolt with a pin through the bolt. When the pin was pulled, the cone washer was free to slide

out of the slot and allowed the bolt to rotate. Although this system functioned satisfactorily, it was too large. In addition, the harness links that slipped over the bolt did not distribute the parachute strap loads properly (figure 11). For these reasons the fittings were redesigned to incorporate a curve shaped rotating link which is pinned at its front end inside of the survival kit (figure 12). Each locking pin is controlled by a piston which is actuated by the gas from an Automatic Inflation Device (FLU-8P) underneath the survival kit lid (figure 13).

4. WATER ACTIVATION DEVICE

Since the U.S. Navy has just finished an extensive qualification program on the FLU-8 Automatic Inflation Device it seemed most practical to utilize this system as the actuator for the harness release to demonstrate an automatic water actuated parachute release feature.

Water can enter the RSSK-8 survival kit through holes drilled in the lid and base. Once the water contacts the FLU-8 actuator it causes the firing of the CO_2 cartridge supplying high-pressure gas to pull the locking pins on either side of restraint links.

If the FLU-8 does not automatically actuate, the crewman can either pull the manual toggle located at the right rear top of the survival kit or manually release himself from the four disconnect/adjuster fittings.

If the XV harness is developed further, then a smaller water activation device will be used.

5. DISCONNECT/ADJUSTMENT BUCKLES

Two of the manual disconnect/adjustment buckles for the XV MOD 2 system were supplied by Teledyne McCormick Selph (TMc/S PN 818545). This parachute release fitting was developed for the U.S. Air Force and has extensive evaluation. It has successfully passed operational test and evaluation by the U.S. Air Force and is currently used in the F-16 aircraft. It appears to provide many improvements over existing fittings.

Other types of disconnect/adjustment buckles will be evaluated on future designs.

6. PRELIMINARY TESTS AT $-G_z$ (TABLE I)

A. Static Tests At The NAVAIRDEVCEN (Figure 14)

Two test subjects (subjects 4 and 5) were inverted in an ESCAPAC ejection seat. Photographs were taken of them with the MA-2 harness and with the XV-MOD 0 harness. Displacement measurements were scaled-off photographs. The results showed that the XV harness provided a 4- to 6-cm (2 to 3 in.) reduction of z displacement when compared to the MA-2 harness.

B. Static Test At The NAVAIRDEVCEN

One test subject (subject #1 using XV MOD 1) was inverted in an ESCAPAC ejection seat which was mounted on the NAVAIRTESTCEN "Negative G" wheel. The subject was inverted a total of ten times with no change of strap adjustment, and an average head displacement was determined. Although the spring-loaded cable transducer provided a precision of ± .001 cm, the poor repeatability for displacement tests of this nature can only give a confidence to ± 1 cm. Therefore, even though the measured improvement of the XV harness over the MA-2 harness was 2.322 cm, it is recorded in Table I as 2 cm.

C. Centrifuge Tests At The NAVAIRDEVCEN (Subjects 2 & 3 using XV MOD 2)

Two tests were conducted on the NAVAIRDEVCEN Centrifuge at $-2G_Z$ during Phase I of the Short-Term Aircrewman Restraint Improvement Program (reference 2).

Displacement measurements were scaled-off photographs. Parallax compensation was made by photographing a metric grid plane located at the seat centerline. A print of this grid was made of clear plastic. This grid was then used on top of photographs showing head displacement. All photographic prints were carefully enlarged by maintaining a fixed distance between two seat reference points.

7. CONFIDENCE IN MEASUREMENTS

Scientific analysis of data requires that measurements be repeatable. Unfortunately, there are too many uncontrollable variables in the "real world" of aircrewman restraint; i.e. how tight straps are pulled; muscle tension; slippage of hardware; friction; aircrewman anthropometry; etc. Therefore, these measurements are quantitatively of little significance, but they do indicate that the XV harness restrains better for $-G_Z$ than the MA-2 harness.

8. ADVANTAGES AND DISADVANTAGES OF THE XV HARNESS

Perhaps the most important advantage of the harness as an inflight restraint is that it provided separate upper and lower torso restraint. If the aircrewman does not adequately tighten his lower restraint before experiencing $-G_Z$ then the upper restraint will take up most of the load.

For quick ground egress in case of fire the XV restraint functions better than any present operational single point release harness because no straps have to slide through or around fittings or other straps. All straps originate and terminate at the two side release fittings (figure 12).

An excellent feature of the XV harness is its ability to automatically release the parachute, restraint, and survival kit upon water immersion. The aircrewman can still retain the survival kit if he wants to, but if he has ejected close to an aircraft carrier he will want to immediately discard anything that might drag him underwater. With less weight to support, the life vest volume can be reduced. This could mean a smaller more comfortable vest with no lobes to entangle shroud lines in the water.

The least investigated aspect of the XV restraint is its effectiveness as a parachute harness. It is planned to have the Aero Systems Recovery Department of the Naval Weapons Center (NAVWEPCEN) redesign it for optimum performance.

It must be emphasized again that these were unplanned preliminary tests done with a limited number of subjects. It is planned to continue this development; future tests will evaluate its full effectiveness as part of the overall life support system.

CONCLUSIONS

Initial tests indicate that the XV restraint offers many advantages over the existing MA-2 harness. These include:

1. Improved inflight restraint; about 3 cm reduction in displacement;
2. Simplified logistics—a seat mounted restraint—one size fits everyone;
3. Reduced emergency egress time; single point release system;
4. Automatic release of parachute, survival kit, and restraint upon water immersion;
5. Improved parachute landing because the survival kit rides higher on the aircrewman and;
6. Low-heat buildup.

Of the 15 features desired in an ideal restraint system (pages 5 and 6) the XV restraint provides all but two (E and F). Provisions for prepositioning of the aircrewman for ejection acceleration, and protection from high-"Q" limb flail could be provided by a separate system or they may be able to be incorporated into this harness.

The SV-2 survival vest with the LPA/LPU life preserver can be worn with this restraint, or the crewman can be equipped with a new life support system which integrates floatation, antiexposure protection, and anti-"G" protection. The items will be considered in the ongoing development.

If all ejection seat equipped aircraft utilize seat mounted harnesses this would mean that the same life support equipment could be used across the board; in fighter aircraft, patrol aircraft, and helicopters. This would greatly simplify supply logistics and result in a significant savings to the U.S. Navy.

RECOMMENDATIONS

1. The XV restraint system should be reviewed by several interested agencies to obtain comments for modifications. The following agencies would provide a good representation:

   a. The U.S. Navy Blue Angels Squadron;

   b. Two Operational Fighter Squadrons;

   c. The NAVAIRTESTCEN;

   d. The NAVWEPCEN Parachute Division;

   e. The Naval Aviation Training Survival School;

   f. The USAF Life Support Office and;

   g. The Aerospace Medical Research Lab.

2. The system should be modified to incorporate any worthwhile ideas.

3. A contract should be issued to produce 12 of the modified systems for test and evaluation.

4. Serious consideration should be given to the possibility of using this type of restraint in the U.S. Navy VTX trainer.

5. A program should be initiated to redesign an integrated life support system compatible with all seat mounted restraints.

6. The survival kit should be made to float by placing all equipment (except for the liferaft) in a partially waterproof ruck sack. The ruck sack would have shoulder straps so that the crewman could pull it out of the survival kit and quickly carry away the equipment. If the kit can be made to float for a couple of minutes, this will give the crewman enough time to disengage any shroud lines.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the excellent workmanship and suggestions provided by Rod Pursell and Bill Schrandt for fabric assembly, and Dick Zabelicky for all hardware. An engineer is only part of a design and development team. Without these master craftsmen this project would have remained a useless paper study.

The author also wishes to acknowledge the fine work of Robert Bason and John Etheredge for clearly defining the problems associated with aircrewman restraint. Their work at the NAVAIRTESTCEN greatly simplified the determination of the XV strap routing.

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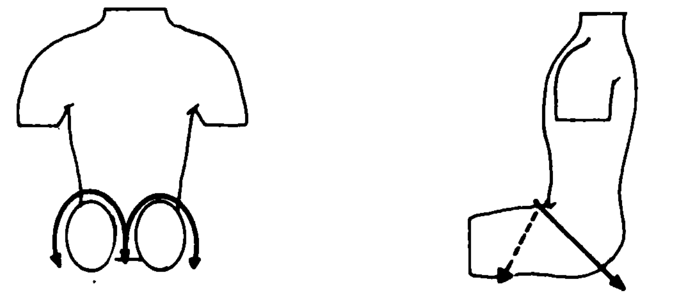
1. "Aircrew Personnel Restraint Subsystems Definition of Deficiencies and Requirements," Lt. R. Bason, USN, and HMZ J. Etheredge, USN, Naval Air Test Center Technical Report SY-28R-78, 24 August 1978.

2. "Centrifuge Tests Of Modifcations To The MA-2 Aircrewman Torso Harness—Phase I," Dan Lorch, Naval Air Development Center Report No. NADC-82126-60, 4 April 1982.

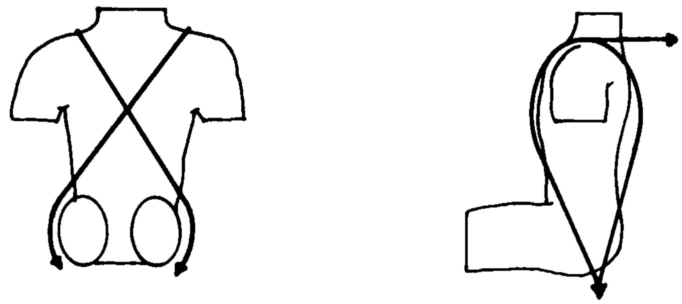
TABLE I

REDUCTION OF Z DISPLACEMENT BY XV RESTRAINT
COMPARED TO THE MA-2 HARNESS

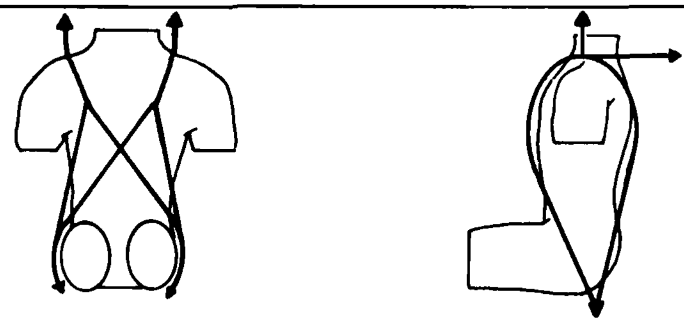
TEST SUBJECT	MASS	ACCELERATION	REDUCTION OF Z DISPLACEMENT
	kg	G_Z	cm
1	71.7	—1	2.0
2	56.8	—2	2.0
3	82.5	—2	2.0
4	77.2	—1	4.0
5	72.8	—1	6.0



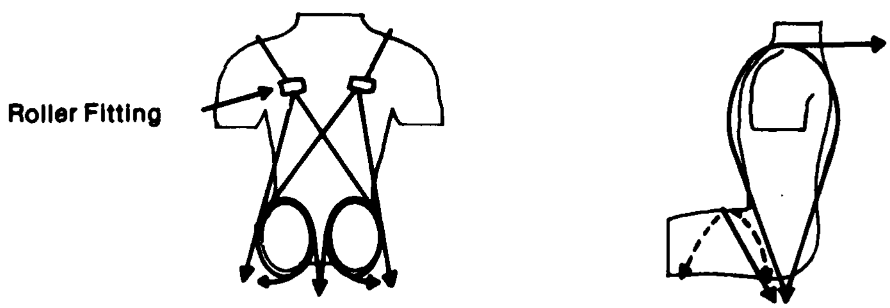
a. LOWER RESTRAINT (FLIGHT LOADS)



b. UPPER RESTRAINT FOR FLIGHT LOADS



c. UPPER RESTRAINT FOR FLIGHT & PARACHUTE LOADS (XV MOD 0)



d. COMPLETE RESTRAINT WITH PROVISION FOR TORSO ROTATION (XV MOD 1 AND 2)

Figure 1. Restraint Strap Routing

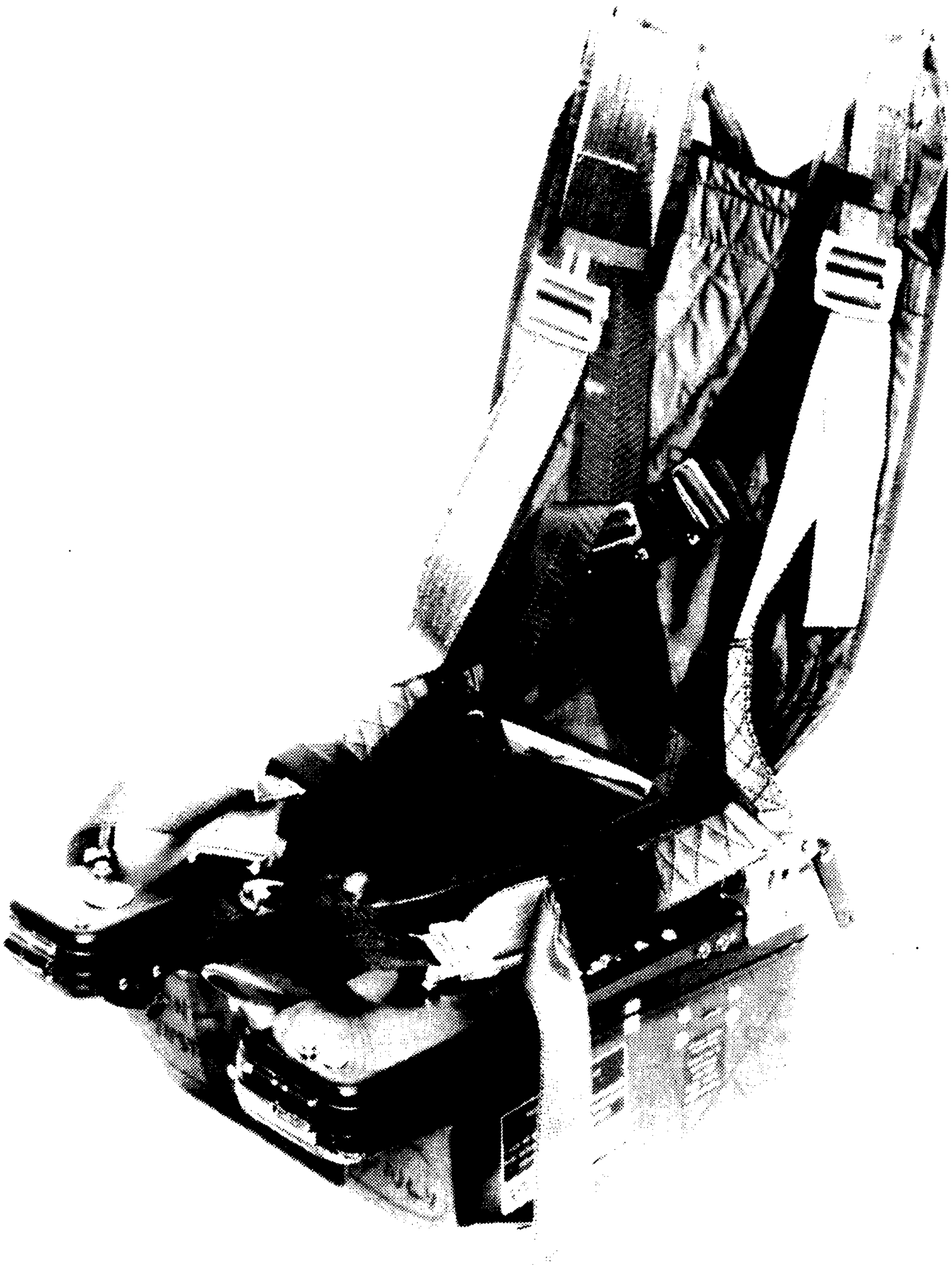


Figure 2. XV MOD 0 Restraint

Figure 3. XV MOD 0 Parachute Suspension

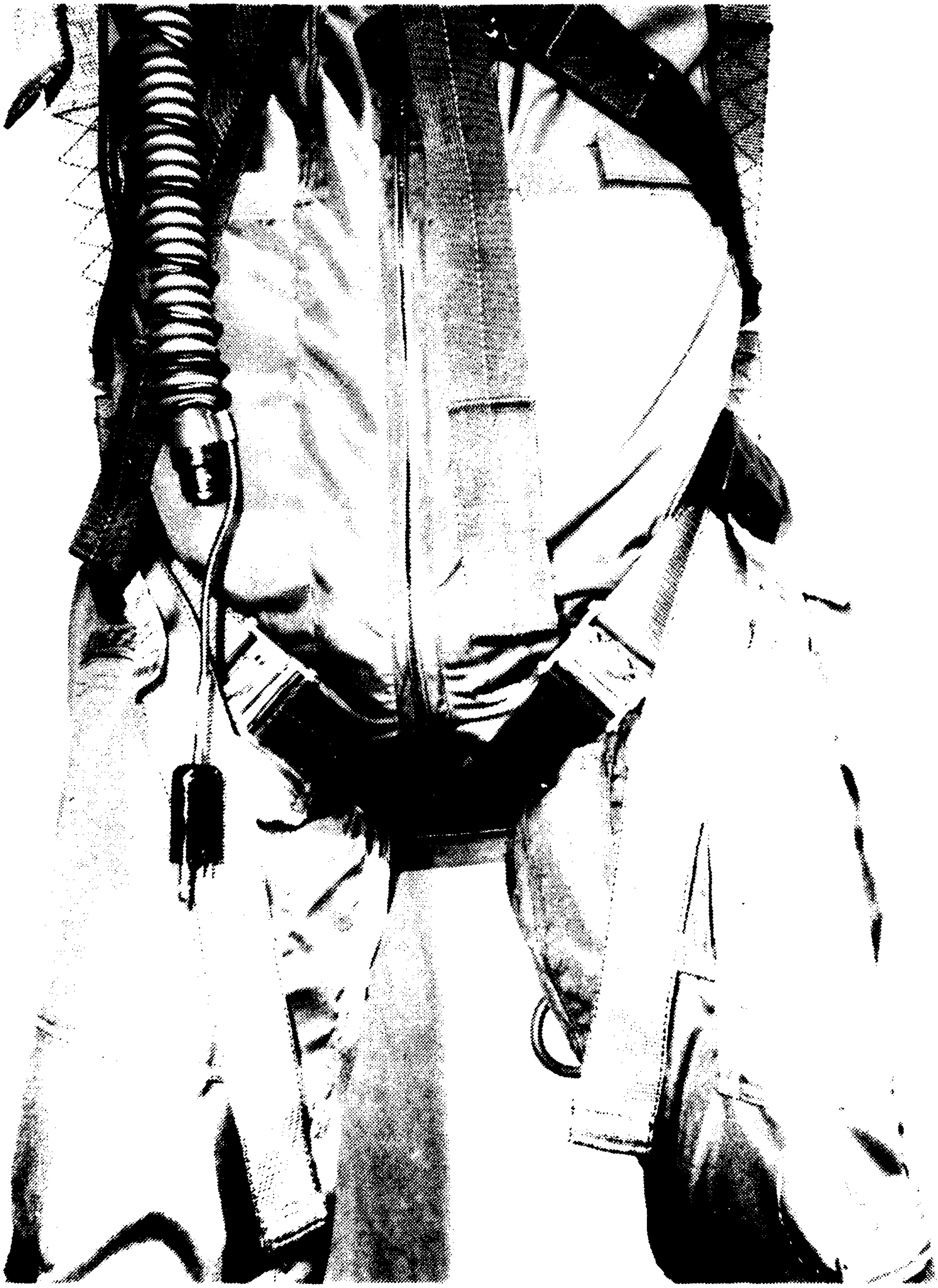


Figure 4. XV MOD 0 Showing Lower Restraint "Wedging"

Figure 5. XV MOD 0 Without Survival Kit (Rear View)

Figure 6. XV MOD 1 With Roller Fitting Which Allows Rotation

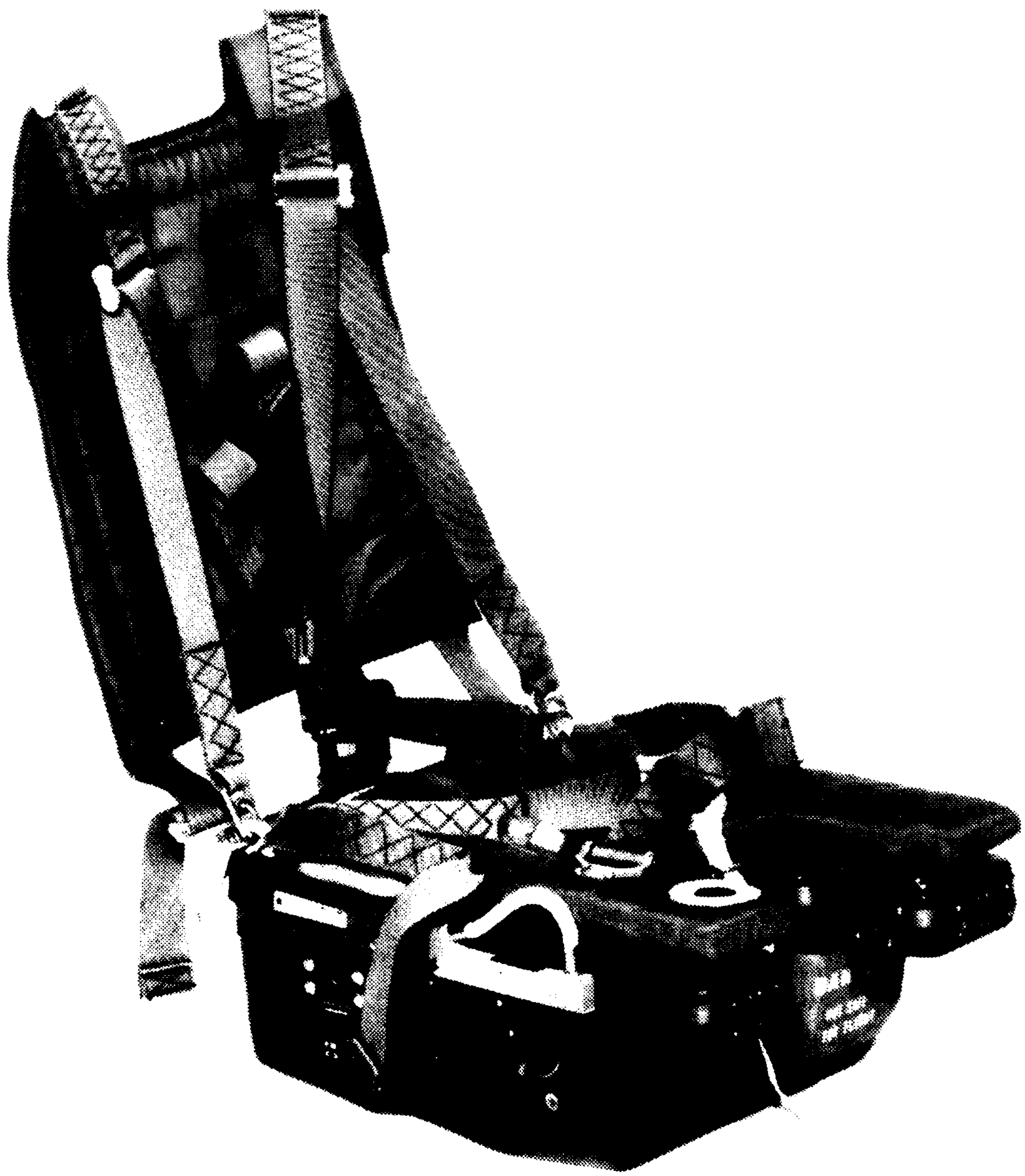
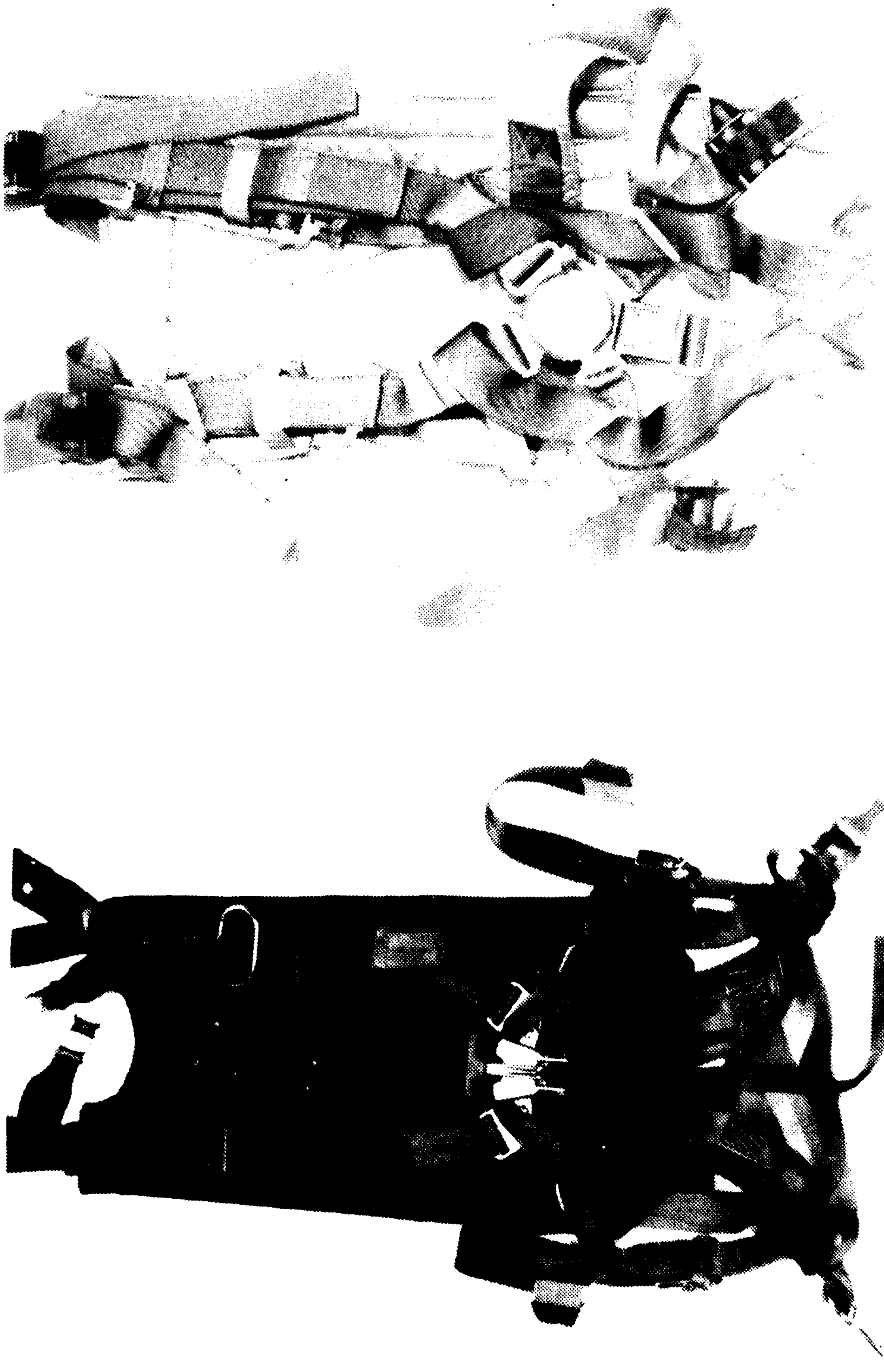


Figure 7. XV MOD 2 With Negative "G" Strap Which Routes Under The Survival Kit

Figure 8. XV MOD 2 With Aircrewman



(a) Martin-Baker Simplified Combined Harness

(b) Stencel Aero Corp. Alpha Jet Harness

Figure 9. Two Samples Of Single Point Release Harness

Figure 10. XV MOD 1 Release Fitting, Rotating Bolt With Cone Shaped Washer

Figure 11. XV MOD 0 And XV MOD 1 Release Fitting With Straps Connected

Figure 12. XV MOD 2 Release Fitting

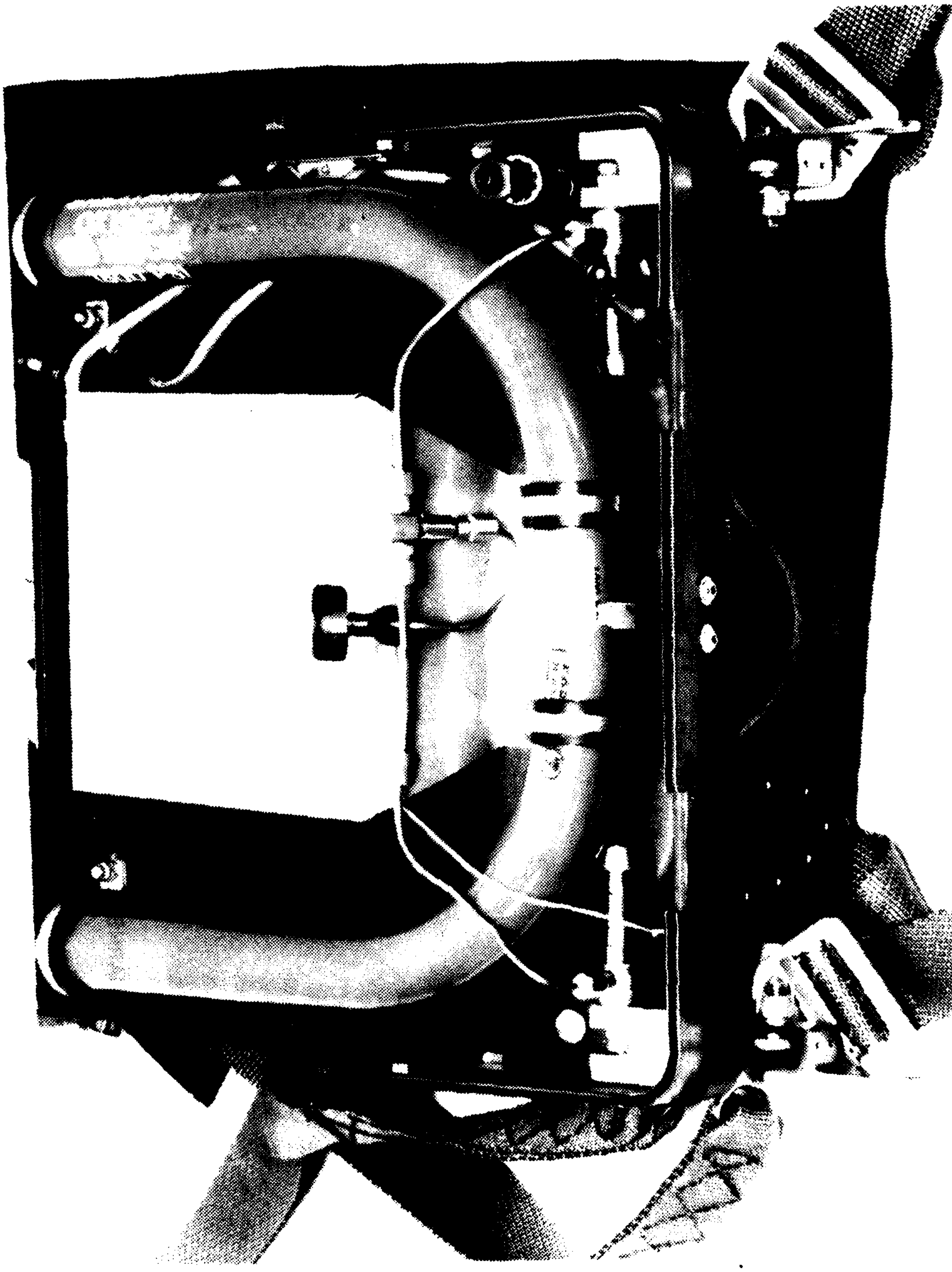
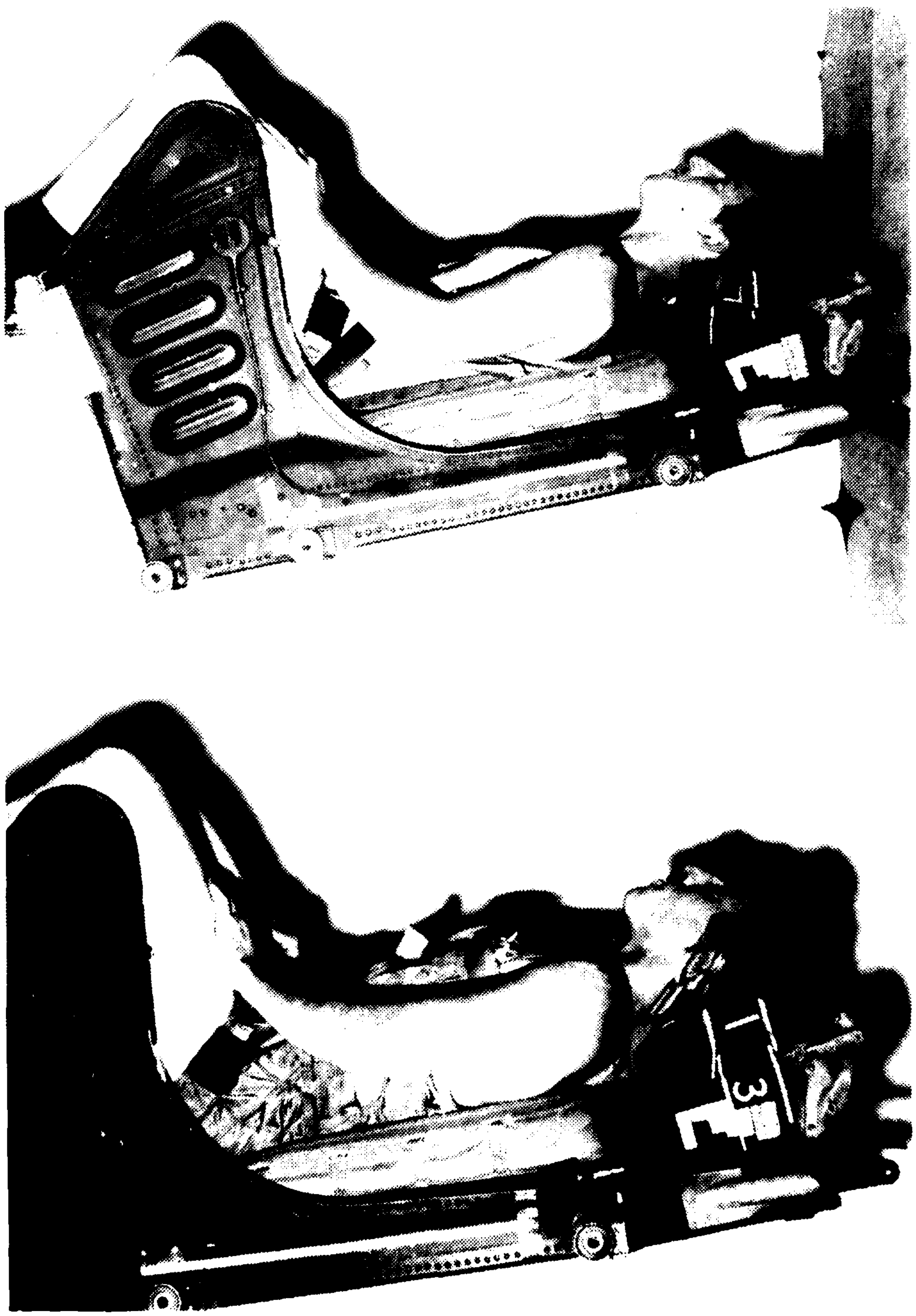


Figure 13. XV MOD 2 Release Fittings, Beneath The Survival Kit Lid



MA-2 HARNESS

XV HARNESS

Figure 14. Sample Comparison Of The MA-2 And XV Harness At $-G_z$ *(Subject #4)*

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